CIVIL, ARCHITECTURAL, AND ENVIRONMENTAL ENGINEERING

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Chair
Brent Stephens

Faculty with Research Interests
For more information regarding faculty visit the Department of Civil, Architectural, and Environmental Engineering website.

The Department of Civil, Architectural, and Environmental Engineering offers graduate programs focused on infrastructure and infrastructure systems, with strengths in structural engineering, transportation engineering, environmental engineering, public works, construction engineering and management, architectural engineering, energy systems engineering, engineering management, and urban systems engineering. The CAEE department maintains close relationships with business, industry, and government organizations and leaders. Our central location in Chicago provides our students with access to an extraordinary range of opportunities, including exploring one of the world’s great cities and the historical and cultural heart of America’s architecture, engineering, and construction (AEC) industry. Our faculty members include a combination of research- and teaching-focused professors and adjunct professors with years of industry experience.

Research Facilities
Research facilities include laboratories devoted to concrete structures, metal structures, building materials, building energy and environmental systems, indoor and outdoor air quality monitoring, transportation engineering, construction engineering and management, and environmental and water resources engineering.

In addition, faculty and graduate students have access to regional facilities such as the Argonne National Laboratory. Also, the department has a computer-aided engineering and design lab equipped with state-of-the-art hardware and software.

Research Areas
The main research areas in the department are architectural engineering, construction engineering and management, environmental engineering, transportation engineering and public works, and structural engineering.

In architectural engineering, faculty conduct research in the built environment, airflow and thermal modeling, indoor air quality, energy and sustainability, and thermal comfort.

Construction engineering and management research involves construction productivity, scheduling and progress control, dispute resolution, construction company organization, sectorial studies, and project management.

Environmental engineering research areas include air resources and water treatment, wastewater treatment, and water resources engineering.

Research in the public works specialty area includes public policy evaluation, management of engineering operations, maintenance, and rehabilitation and construction of civil infrastructures such as roads, bridges, and traffic safety hardware.

Structural engineering research concentrates on structural dynamics and earthquake resistant design, structural health monitoring, computational mechanics, and bridge engineering.

Transportation engineering research areas include multimodal transportation infrastructure and dynamic traffic network mobility, safety, security and emergency management, transportation asset management, and network economics.

Admission Requirements
Minimum Cumulative Undergraduate GPA
3.0/4.0
Minimum GRE Scores
- Master's/Master of Science: 292 (quantitative + verbal), 2.5 (analytical writing)
- Ph.D.: 292 (quantitative + verbal), 2.5 (analytical writing)

Minimum TOEFL Scores
80/213 (internet-based/paper-based test scores)

Note: the GRE requirement is waived for master of engineering degree applicants who hold a bachelor of science in a related field from an ABET-accredited university in the U.S. with a minimum GPA of 3.0/4.0.

Meeting the minimum GPA and test score requirements does not guarantee admission. Test scores and GPA are just two of many factors considered.

Each full-time graduate student is assigned a faculty adviser at the time of initial registration. Part-time or non-degree students who have not been assigned an adviser and who intend to pursue a degree should contact the department for counseling before registering for courses.

Degree Programs
- Master of Engineering Management, Project Management Track
- Master of Engineering in Architectural Engineering
- Master of Engineering in Construction Engineering and Management
- Master of Engineering in Environmental Engineering
- Master of Engineering in Structural Engineering
- Master of Engineering in Transportation Engineering
- Master of Engineering in Urban Systems Engineering
- Master of Public Works
- Master of Science in Architectural Engineering
- Master of Science in Civil Engineering with specialization in:
  - Construction Engineering and Management
  - Structural Engineering
  - Transportation Engineering
- Master of Science in Environmental Engineering
- Doctor of Philosophy in Architectural Engineering
- Doctor of Philosophy in Civil Engineering
- Doctor of Philosophy in Environmental Engineering

Interdisciplinary Programs
- Master of Engineering in Environmental Engineering with Specialization in Energy/Environment/Economics (E3)

Certificate Program in Architectural Engineering
- Architectural Engineering
- Building Energy Modeling

Certificate Programs in Civil Engineering
- Construction Management
- Earthquake and Wind Engineering Design
- Infrastructure Engineering and Management
- Transportation Systems Planning
Course Descriptions

CAE 502
Acoustics and Lighting
Lecture: 3 Lab: 0 Credits: 3

CAE 503
Advanced Structural Analysis
Prerequisite(s): CAE 411 with min. grade of C or MMAE 501* with min. grade of C or CAE 514* with min. grade of C or Graduate standing, An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 Lab: 0 Credits: 3

CAE 504
Seismic Retrofit and Earthquake Hazard Reduction
Prerequisite(s): CAE 529 with min. grade of C
Lecture: 4 Lab: 0 Credits: 4

CAE 505
Applications of Computational Fluid Dynamics in Engineering
The course introduces concepts of computational fluid dynamics (CFD) and focuses on engineering applications of CFD. Students will learn how to use CFD tools to model internal and external flows in a wide range of architectural, chemical, civil, and mechanical engineering applications. Projects offer students flexibility in selecting their applications. Example semester long projects include design of room air distribution systems, indoor and outdoor air quality, natural ventilation, heat transfer coefficient calculations, pipe flow, rotating reference frame, and more.
Lecture: 3 Lab: 0 Credits: 3

CAE 506
Building Envelope Rehabilitation
Repair and rehabilitation of existing building exterior envelopes. The course will include problem identification, investigative techniques, repair methods, preparation of remedial design documents and general management of rehabilitation projects. Types of constructions include buildings, exterior walls, facades, cladding, roofing, plazas, porches, fire escapes, and others.
Lecture: 3 Lab: 0 Credits: 3

CAE 508
Advanced Bridge Engineering
Specifications for bridge design and evaluation. Advanced bridge design and evaluation topics such as design load envelope, seismic load design, bridge condition rating, bridge load rating, and steel bridge fatigue evaluation. Bridge management systems. Life cycle analyses. Use of high performance materials in bridge engineering.
Prerequisite(s): CAE 408 with min. grade of C or Graduate standing
Lecture: 3 Lab: 0 Credits: 3

CAE 510
Dynamics of Fire
Introduction to fire, physics and chemistry, and mass and heat transfer principles, fire fluid mechanic fundamentals, fundamentals and requirements of the burning of materials (gases, liquids, & solids), fire phenomena in enclosures such as pre-flashover and post-flashover.
Lecture: 3 Lab: 0 Credits: 3

CAE 511
Fire Protection of Buildings
Fundamentals of building design for fire and life safety. Emphasis on a systematic design approach. Basic considerations of building codes, fire loading, fire resistance, exit design, protective systems & other fire protection systems. For architects, and engineers not majoring in fire protection and safety engineering.
Lecture: 3 Lab: 0 Credits: 3

CAE 513
Building Science
Study of the physical interactions between buildings, people, and climate (i.e., temperature, humidity, wind, sun, rain, snow, etc.). Topics include: heat transfer, psychrometrics, thermal comfort, indoor air quality, ventilation, infiltration, solar insolation, heating and cooling load calculations, building energy efficiency, and building codes.
Lecture: 3 Lab: 0 Credits: 3

CAE 514
Mathematical Methods for Structural Engineering
Lecture: 3 Lab: 0 Credits: 3
CAE 515
Building Information Modeling Applications for Building Performance
Building Information Modeling (BIM) is at the core of building performance optimization and sustainability, making it possible to model performance while tracking construction of the building in sequence. This course builds essential knowledge of building performance optimization using BIM processes and provides the necessary background and skills to use BIM with building energy simulation software tools. Autodesk Revit with Insight will be used as the primary design authoring, manipulation, and analysis tool. Secondary Autodesk BIM tools such as Formit for building massing and orientation; recap for existing conditions capturing; Navisworks for interference checking and design collaboration; revit Live for Virtual Reality visualizations and presentations; and BIM 360 Ops for facility management and operation will also be used in class. Proven methods for using BIM to address essential building performance and sustainability issues will be presented using real-world examples, placing particular emphasis on using BIM for analysis of design alternatives for the life cycle of a building. Complete with coverage of sustainability, integrated design, and lean construction requirements, this is a valuable course for architects, architectural engineers, MEP engineers, facility managers, and other construction professionals involved in building performance modeling and optimization.
Lecture: 3 Lab: 0 Credits: 3

CAE 517
HVAC Systems Design
Study of the fundamental principles and engineering procedures for the design of heating, ventilating, and air conditioning systems; HVAC system characteristics; system and equipment selection; duct design and layout. Attention is given to energy conservation techniques and computer applications.
Prerequisite(s): CAE 331 or CAE 513
Lecture: 3 Lab: 0 Credits: 3

CAE 518
Advanced Reinforced Concrete
Advanced topics in behavior and mechanics of reinforced concrete members: ultimate flexural strength, development of reinforcement, moment-curvature analysis, non-linear deflections, two-way slabs, deep beams, torsion, columns with biaxial bending, slender columns, and numerical methods. Strong emphasis is placed on the underlying structural behavior and its influence on building codes and design standards.
Prerequisite(s): CAE 432* with min. grade of C or Graduate standing. An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 Lab: 0 Credits: 3

CAE 519
Structural Forensic Engineering
Introduction to structural forensic engineering as relates to civil and architectural engineering. Application of engineering principles to failure investigations including understanding the causes of failures, and safety issues at collapsed sites. Field investigations and data gathering including the use of sensor technology, sampling, and structural monitoring. Understanding the effects of the environment on the properties of common structural materials. Evaluation of distress conditions such as vibrations, cracks, metal fatigue, excessive deformation resulting from creep and inelasticity, thermal effects, fire damage, effects of extreme loading conditions, and localized failures. Preparation of forensic reports, presenting results of evaluations of failed structural systems and structural distress conditions, insurance/legal issues, responsibility of engineer and ethics issues. Review of case studies.
Lecture: 3 Lab: 0 Credits: 3

CAE 520
Buckling of Structures
Prerequisite(s): CAE 431 with min. grade of C and CAE 411 with min. grade of C
Lecture: 4 Lab: 0 Credits: 4

CAE 522
Structural Model Analysis
Prerequisite(s): CAE 503 with min. grade of C
Lecture: 2 Lab: 2 Credits: 4

CAE 523
Statistical Analysis of Engineering Data
Descriptive statistics and graphs, probability distribution, random sampling, independence, significance tests, design of experiments, regression, time series analysis, statistical process control, and introduction to multivariate analysis.
Lecture: 3 Lab: 0 Credits: 3

CAE 524
Building Enclosure Design
Design of building exteriors, including the control of heat flow, air and moisture penetration, building movements, and deterioration. Study of the principle of rain screen walls and of energy conserving designs. Analytical techniques and building codes are discussed through case studies and design projects.
Prerequisite(s): CAE 513 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3
CAE 525
Advanced Steel Structures
Prerequisite(s): CAE 431* with min. grade of C or Graduate standing. An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 Lab: 0 Credits: 3

CAE 526
Energy Conservation in Buildings
Prerequisite(s): CAE 331 or CAE 513
Lecture: 3 Lab: 0 Credits: 3

CAE 529
Dynamics of Structures
Prerequisite(s): CAE 411 with min. grade of C or Graduate standing
Lecture: 3 Lab: 0 Credits: 3

CAE 530
Finite Element Method of Analysis
Advanced and special topics in finite element analysis such as finite element-boundary element method, plates, and shell analysis using finite elements.
Prerequisite(s): CAE 411 with min. grade of C or Graduate standing
Lecture: 3 Lab: 0 Credits: 3

CAE 532
Analysis of Plates and Shells
Exact and approximate stress analysis of elastic, isotropic plates of various shapes acted upon by forces in their plane, as well as transverse forces. Stability of plates with various edge conditions, orthotropic plates, elastically supported plates and simple cylinders. Approximate methods such as finite differences, finite elements and the methods of Ritz and Galerkin.
Prerequisite(s): CAE 503 with min. grade of C
Lecture: 4 Lab: 0 Credits: 4

CAE 533
Theory and Analysis of Thin Shells
Differential geometry of surfaces. Elastic theory of general shells with nonorthogonal curvilinear coordinates. Specialization to cylindrical shells, shells of revolution and translational shells. Exact and approximate solutions applied to the bending membrane theories of thin shells. Approximate methods including finite differences, finite elements and methods associated with Ritz, Galerkin, Puchler and Gaekler.
Prerequisite(s): CAE 503 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3

CAE 534
Computational Techniques in Finite Element Analysis
Survey of numerical methods as applied to FEM software. Database management, equation solvers, eigen value routines and schemes for direct integration (both implicit/explicit), all as employed in the development of a finite element program. Topics covered also include band and front minimizers, static and dynamic substructuring via super elements and sensitivity studies. Same as MAE 538.
Prerequisite(s): CAE 530* with min. grade of C or Graduate standing. An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 Lab: 0 Credits: 3

CAE 535
Nonlinear Finite Element Analysis
FEM as applied to nonlinear problems. Contact problems, the mechanics of large deformation, full and updated Lagrange formulations, review of plasticity, solution algorithms, Eulerian approaches, application to FEM to limit analysis. Same as MAE 539.
Prerequisite(s): CAE 442 with min. grade of C or MMAE 501 with min. grade of C or CAE 514 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3

CAE 537
Homeland Security Concerns in Building Designs
Review of blast effects produced by solid phase weapons and their effects on structures and people. Estimation of the risk of a terrorist attack and the corresponding threat. Review of simplified methods for the analysis and design of structures to meet homeland security concerns and procedures to minimize casualties. Analysis of post event fires and how to prevent them. Review of security measures to minimize the effects of blast on buildings and people.
Lecture: 3 Lab: 0 Credits: 3

CAE 538
Control of Building Environmental Systems
Prerequisite(s): CAE 331 or CAE 513 with min. grade of C or MMAE 322
Lecture: 3 Lab: 0 Credits: 3
CAE 539
Introduction to Geographic Information Systems
Geographic information system (GIS) technology allows users to combine tabular information with maps, creating powerful spatial databases which display and query information in new ways. This course will teach general GIS and GPS skills and concepts, useful to students and practitioners in a variety of disciplines. Students will complete a final GIS project relevant to their field of study. This hands-on class will use ESRI's ArcView and Spatial Analyst products, as well as Trimble GeoExplorer GPS units.
Lecture: 3 Lab: 0 Credits: 3

CAE 540
Asphalt and Concrete Mix Design
Types of asphalt and physical properties of asphalt. Types of mixes: dense graded, open graded, base courses, and maintenance mixes. Types of pavement structures and hot mix asphalt placement. Aggregate physical properties, tests, and blending. Maintenance and rehabilitation materials. Mixture design procedures, including Marshall and Hveem procedures, and weight-volume relationships. Evaluation of mixture properties, engineering property's importance to performance, resilient modulus, fatigue, and creep testing, and thermal cracking properties. Laboratory included.
Lecture: 2 Lab: 3 Credits: 3

CAE 541
Pavement Evaluation and Management
Pavement management systems (PMS) concepts, network definition, condition survey, pavement condition index (PCI), non-destructive deflection testing (NDT), measurement of roughness and skid resistance, micropaver PMS, PMS implementation, project and network-level management, maintenance alternatives, development of annual and long-range work plans.
Lecture: 3 Lab: 0 Credits: 3

CAE 543
Demand Models for Urban Transportation
Fundamental theory of supply and demand, transportation economics, network equilibrium, land use and transportation equilibrium. Demand models: trip generation, geographical distribution, mode split, route assignment, the direct-demand model and disaggregate-behavioral-demand models. Special properties of models. Relationships among models.
Lecture: 3 Lab: 0 Credits: 3

CAE 544
Urban Transportation Planning
Exploration of the goals of urban transportation. Program planning in relating transportation technology to social, economic, and environmental systems. Systems analysis in forecasting urban land use and travel demand and evaluating alternatives in transportation planning to reach a balance between demand and supply.
Lecture: 4 Lab: 0 Credits: 4

CAE 545
Traffic Operations and Flow Theory
Studies of space and time distribution of speed and other traffic characteristics in the transportation network. Macro, micro, and mesoscopic traffic flow theories. Simulation in traffic networks. Application of flow theories to traffic control and operations.
Lecture: 3 Lab: 0 Credits: 3

CAE 546
Public Transportation Systems
Lecture: 3 Lab: 0 Credits: 3

CAE 547
Advanced Traffic Engineering
Data collection, statistical analysis, and interpretation of traffic information. Advanced traffic engineering topics such as signaling, street-and-highway capacity analysis, and highway safety research.
Lecture: 3 Lab: 0 Credits: 3

CAE 548
Transportation Systems Management
Transportation as a system. Problems of traffic congestion, land use/transportation intersection; intersection control; freeway and arterial incident management; safety considerations; evaluation of strategies; case studies.
Lecture: 3 Lab: 0 Credits: 3

CAE 549
Transportation Economics, Development and Policy
Application of managerial, micro- and macroeconomic concepts to transportation systems. Investment and impact analysis. Transport policy as it relates to social, economic and environmental issues. Legislative actions affecting transport issues.
Lecture: 3 Lab: 0 Credits: 3

CAE 550
Applied Building Energy Modeling
This course introduces students to building energy modeling software and techniques that are widely used in industry applications. The course is practice-oriented and builds upon building energy modeling methods as they are practiced in engineering offices (using IES software). The course centers on the two most common types of energy models in practice: (1) models for LEED and code compliance, and (2) parametric models for evaluating energy conservation measures. During the first half of the course, students will learn modeling methods and assumptions to create an energy model of an actual building project for the LEED Energy and Atmosphere credit with all supporting documents required for LEED submission. In the second half of the course, students will learn to analyze energy conservation measures using parametric energy models. The course will also focus on advanced energy modeling topics, such as modeling HVAC systems and controls, passive techniques, composite fenestration, thermal bridges, thermal mass, and others. At the end of the course, students will have two complete energy models that they can use in their portfolio.
Prerequisite(s): CAE 331 or CAE 513
Lecture: 3 Lab: 0 Credits: 3
**CAE 551**  
**Prestressed Concrete**  
Fundamental behavior, mechanics, and design of prestressed concrete members and structures. Service loading, ultimate strength, computation of prestress losses, deformations, and precast concrete components. Exposure to relevant building code provisions, design standards, and industry recommended practice. The opportunity for students to compete in a prestressed concrete beam fabrication and design competition may also be offered.  
**Prerequisite(s):** CAE 432  
**Lecture:** 3  
**Lab:** 0  
**Credits:** 3

**CAE 553**  
**Measurement and Instrumentation in Architectural Engineering**  
Hands-on experience with energy and indoor environmental quality measurements in buildings including experimental design, data analysis, and experimental statistics. Measurements and techniques covered include: thermal performance (e.g., temperature, humidity, and heat flux); fluid flows and HVAC characteristics (e.g., velocity, pressure, and airflow rates); energy performance (e.g., current, voltage, and power draw); whole building diagnostics (e.g., envelope airtightness, ventilation performance, and duct leakage testing); and indoor air quality (e.g., tracer gas techniques, particle measurements, and gas measurements). Course combines lectures and field measurements in buildings on campus.  
**Lecture:** 3  
**Lab:** 0  
**Credits:** 3

**CAE 554**  
**Building Commissioning**  
This course introduces students to the fundamentals and practice of building commissioning and prepares students for the Building Commissioning Professional (BCxP) Certification Exam. Building commissioning is an integrated process of quality assurance (QA), quality control (QC), and communications that is utilized to ensure that all of its systems, including mechanical, electrical, lighting, plumbing, fire protection, acoustical, and controls, perform interactively and according to the design intent. Building commissioning also ensures that building operators are prepared to operate and maintain its systems and equipment, which saves time, money, and energy, and improves the sustainability and resilience of buildings. This course is open to all majors with familiarity in buildings and their systems.  
**Prerequisite(s):** CAE 331 or CAE 513  
**Lecture:** 3  
**Lab:** 0  
**Credits:** 3

**CAE 555**  
**Transportation Systems Evaluation**  
Concepts and principles of transportation economic analysis, transportation costs and benefits, user and nonuser consequences, needs studies, finance and taxation, methods for evaluation of plans and projects, cost-efficiency, cost-effectiveness, environmental impact assessment, and economic development assessment.  
**Lecture:** 3  
**Lab:** 0  
**Credits:** 3

**CAE 556**  
**Net Zero Energy Building Design I**  
An interdisciplinary project-based course in which students work in teams to design and provide full design documentation for a net zero energy building, meaning that it combines energy efficiency and renewable energy generation to consume only as much energy as can be produced onsite through renewable resources on an annual basis. Teams are expected to effectively and affordably integrate principles of building science, construction engineering and management, economic analysis, and architectural design in an integrated design process. Teams are required to submit full sets of plans, drawings, renderings, construction details, and analyses for energy efficiency, costs, affordability, environmental justice, equity, sustainability, and resiliency. The course aligns with a design competition, typically the Department of Energy's Solar Decathlon Design Challenge. The course prepares the next generation of architects, engineers, and construction managers with skills and expertise to start their careers and generate creative solutions for real-world net zero energy buildings. CAE 556 is the first course in a two-course series.  
**Lecture:** 3  
**Lab:** 0  
**Credits:** 3

**CAE 557**  
**Net Zero Energy Building Design II**  
An interdisciplinary project-based course in which students work in teams to design and provide full design documentation for a net zero energy building, meaning that it combines energy efficiency and renewable energy generation to consume only as much energy as can be produced onsite through renewable resources on an annual basis. Teams are expected to effectively and affordably integrate principles of building science, construction engineering and management, economic analysis, and architectural design in an integrated design process. Teams are required to submit full sets of plans, drawings, renderings, construction details, and analyses for energy efficiency, costs, affordability, environmental justice, equity, sustainability, and resiliency. The course aligns with a design competition, typically the Department of Energy's Solar Decathlon Design Challenge. The course prepares the next generation of architects, engineers, and construction managers with skills and expertise to start their careers and generate creative solutions for real-world net zero energy buildings. CAE 557 is the second course in a two-course series.  
**Prerequisite(s):** CAE 556 with min. grade of C  
**Lecture:** 3  
**Lab:** 0  
**Credits:** 3

**CAE 558**  
**Urban Systems Engineering Design**  
CAE 558 is a project-based course where students will explore integrated designs of urban systems. Each project will apply the students' engineering disciplines (such as structures, transportation, building science, construction engineering and management, environmental engineering) in a comprehensive analysis that considers the economic, human, and environmental issues associated with the project.  
**Lecture:** 3  
**Lab:** 0  
**Credits:** 3
CAE 559
Urban Systems Engineering Seminar
CAE 559 is an active seminar course that emphasizes current topics in urban systems engineering. Invited speakers will include researchers and representatives from current practice such as municipal and regional planners and consultants. Appropriate readings will be assigned in advance of each speaker to guide students in preparation for active discussion with each speaker. Each student will also write a term paper on an urban systems engineering topic of their choice, connecting material from the assigned reading, the speakers, and additional references selected by the student.
Lecture: 3 Lab: 0 Credits: 3

CAE 560
Plastic Methods
Prerequisite(s): CAE 431* with min. grade of C and CAE 503* with min. grade of C. An asterisk (*) designates a course which may be taken concurrently.
Lecture: 4 Lab: 0 Credits: 4

CAE 561
Structural Reliability and Probabilistic Bases of Design
Fundamentals of probability theory and stochastic processes; statistical analysis of engineering data; probabilistic modeling of structural loads and material properties. Reliability analysis and design of structure, reliability-based design criteria. Evaluation of existing design codes. Safety analysis of structures under fatigue loads. Fault and event tree analysis.
Prerequisite(s): CAE 307 with min. grade of C or Graduate standing
Lecture: 3 Lab: 0 Credits: 3

CAE 562
Engineering Behavior of Soil
Soil mineralogy and soil fabric, soil-water electrolyte system, dispersive clay, stress and strain analyses, elastic equilibrium in soil masses, plastic equilibrium in soil masses, in situ and laboratory stress paths, shear strength of sands and clays, thermal properties of soils, critical state soil mechanics principles, nonlinear pseudo elastic and elastoplastic constitutive models.
Lecture: 4 Lab: 0 Credits: 4

CAE 563
Advanced Soil Mechanics Laboratory
Advanced aspects of soil property measurement with application to design and analysis, system characteristics on soil sediment, pinhole test for identifying dispersive clays, consolidation, triaxial compression and triaxial extension with porewater measurement, cyclic triaxial test, permeability with back pressure, determination of critical void ratio.
Prerequisite(s): CAE 323 with min. grade of C or Graduate standing) and CAE 562* with min. grade of C. An asterisk (*) designates a course which may be taken concurrently.
Lecture: 1 Lab: 3 Credits: 1

CAE 564
Design of Foundations, Embankments and Earth Structures
Consolidation phenomena, derivation of bearing capacity equations, beams and slabs on soils, piles and pile groups, compaction, earth pressure theories and pressure in embankment, slope stability analyses, retaining structures, embankment design, soil structure interaction during excavation, design of anchors for landslide stabilization and retaining structures and instrumentation.
Prerequisite(s): (CAE 323 with min. grade of C or Graduate standing) and CAE 457 with min. grade of C
Lecture: 4 Lab: 0 Credits: 4

CAE 565
Rock Mechanics and Tunneling
Rock classification for engineering purposes, mechanical behavior of rocks, in situ stresses in rock, stresses around underground openings, rock slope engineering, design of underground structures, design of deep support excavation and tunnels, primary and secondary linings of tunnels, mined shafts, instrumentation.
Prerequisite(s): CAE 457 with min. grade of C
Lecture: 4 Lab: 0 Credits: 4

CAE 566
Earthquake Engineering and Soil Dynamics
Earthquakes and their intensity, influence of group motion, review of I-DOF and M-DOF systems, wave propagation theories, vibration due to blast and shock waves, design earthquake motion, dynamic properties of soils, soil liquefaction, bearing capacity during earthquakes and design of machine foundations, isolation of foundations, pile foundation, and dynamic analysis, earth pressure during earthquakes on retaining structures and embankment.
Prerequisite(s): (CAE 323 with min. grade of C or Graduate standing) and CAE 420 with min. grade of C
Lecture: 4 Lab: 0 Credits: 4

CAE 568
Transportation Asset Management
Processes and techniques for managing the preservation and expansion of highway transportation facilities such as pavements, bridges, and traffic control and safety hardware; system usage concerning mobility, safety and security, energy consumption, and vehicle emissions; and economic development impacts. Five component management systems are first examined: pavements, bridges, traffic control and safety hardware, roadway maintenance, safety, and congestion. Finally, the methodology for overall transportation asset management is discussed. The primary emphasis is on data collection, database management, performance modeling, needs assessment, project evaluation, project selection, program development strategies, risk and uncertainty modeling, and institutional issues.
Lecture: 3 Lab: 0 Credits: 3
CAE 569
Construction Methods, Cost Estimating, and Project Budgeting
The role of program management and project budgeting in establishing a construction project, estimating in construction design and contract administration. Types of estimates, unit costs and production rates; job costs. Preparing bid for complete building project using manual methods and the CSI format; checking quantity take-off and cost estimating in selected divisions using a computer software package.
Lecture: 3 Lab: 0 Credits: 3

CAE 570
Legal Issues in Civil Engineering
This course introduces students to the legal aspects of engineering and construction, contract documents, and contract clauses. Upon completion of this course, students will be able to do the following: (1) identify the elements of contract formation; (2) interpret contract clauses; (3) explain the rights and duties of the parties involved in design and construction; and (4) evaluate changes and their root causes. Students will also be able to objectively identify and analyze legal liabilities and the expected professional standard of architects, engineers, and contractors.
Lecture: 3 Lab: 0 Credits: 3

CAE 571
Lean Construction and Control
This course introduces students to lean principles and the lean project delivery system (LPDS) applied to the construction industry. Lean construction and lean project delivery embrace concepts and techniques originally conceived in the automobile manufacturing industry and adopted by the construction industry. In the manufacturing sector, lean production has revolutionized product manufacturing, resulting in significant gains in plant productivity, reliability, and reductions in defects. Specific concepts that will be covered in this course include Plan-Do-Check-Act continuous improvement, A3 reporting, value stream mapping, pull systems and pull planning, kanban, SS, standardization, and the Choosing by Advantages Decisionmaking System.
Lecture: 3 Lab: 0 Credits: 3

CAE 572
Construction Business Operations and Cost Accounting & Control
Lecture: 3 Lab: 0 Credits: 3

CAE 573
Construction Management with Building Information Modeling
Fundamentals and practical use of information technologies in the construction industry; basic concepts of building information modeling (BIM); review of software and technology available for BIM; practical use of BIM including design and clash detection; impact of BIM on construction management functions; construction scheduling and sequencing using BIM; cost estimating using BIM; facility management with BIM; integrated approach to navigate BIM as a multi-disciplinary design, analysis, construction, and facility management technology; class exercise to create a BIM model and to use it in scheduling, sequencing, cost estimating, management, and simulation of a construction project.
Lecture: 3 Lab: 0 Credits: 3

CAE 574
Economic Decision Analysis in Civil Engineering
Basic economic concepts including interest calculations, economic comparison of alternatives, replacement decisions, depreciation and depletion, tax considerations, and sensitivity analysis. Evaluation of public projects, the effect of inflation, decision making under risk and/or uncertainty, economic decision models. Case studies from the construction industry.
Lecture: 3 Lab: 0 Credits: 3

CAE 575
Systems Analysis in Civil Engineering
Management and system concepts, linear programming, graphical methods, Simplex, two-phase Simplex, the transportation problem, the assignment problem, integer programming, and sensitivity analysis. System modeling by activity networks; maximal-low flow, longest-path and shortest-path analyses, flow graphs, decision-tree analysis, stochastic-network modeling, queuing systems, and analysis of inventory systems. Case studies from the construction industry.
Lecture: 3 Lab: 0 Credits: 3

CAE 576
Applications of Unmanned Aerial Vehicles (UAVs or "Drones") for Construction Projects
This course will introduce knowledge on Unmanned Aerial Systems (UAS) for construction projects. UAS are systems, such as Unmanned Aerial Vehicles (UAVs) that require a level of autonomy with minimal or no intervention from project actors to navigate over job-site environments. Instruction and learning activities incorporate all steps of processing UAV information. Laboratory activities include the design of plans to collect, analyze, and draw conclusions from UAV data and the sharing of experimental results with peers and faculty. Students will have access to a university-provided UAV equipped with advanced software for image processing, high-definition video camera, data communication platforms, and positioning sensors to capture a physical environment and register telemetry data related to their projects.
Lecture: 3 Lab: 0 Credits: 3
CAE 577

Construction Equipment Management
Factors affecting the selection of construction equipment. Descriptions, operating methods, production rates, unit costs related to excavating equipment. Power shovels, draglines, clam shells, and trenching machines. Engineering fundamentals. Moving construction equipment, including trucks, wagons, scrapers, dozers, soil-stabilization and compaction equipment. Belt conveyors, compaction and drilling equipment, pile driving equipment, pumps and crushers.
Lecture: 3 Lab: 0 Credits: 3

CAE 578

Construction Claims Management
This course provides a basic explanation of construction contract claims by types such as delays, acceleration, and scope issues, the underlying legal theories of the contract construction and claims, elements required for each claims type defenses to the claim, prophylactic claims measures. The claims process within the contract and extra-contractual basis’s for claims are examined. Resolution of claims by ADR techniques and the formal litigation process are explained. AIA, AGC, and federal claims provisions are described. In addition to construction contract claims other types of claims associated with construction projects are covered such as Surety bond claims and various insurance claims (CGL, Builder’s Risk, workers comp, etc)
Prerequisite(s): CAE 473 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3

CAE 579

Real Estate Fundamentals for Engineers and Architects
The objective of this course is to introduce civil engineering students to the real estate process. Students will learn techniques and methodologies for evaluating real estate investment opportunities using engineering economic analysis principles. Students will use Time Value of Money analysis for evaluating real estate transactions, including how to carry out calculations using formulas, financial calculators, and spreadsheets. This course will help civil engineering students learn financial skills that can be applied to professional and personal investment decisions.
Lecture: 3 Lab: 0 Credits: 3

CAE 580

Intelligent Transportation Systems
The concept of intelligent transportation systems (ITS) involves the use of rapidly emerging information and communication technologies in mitigating congestion and attendant problems. A substantial amount of research and development activities have taken place over the last few decades. This course will provide an introduction to the various aspects of ITS and will focus on ITS planning, technology, big data analysis, and evaluation. In addition, such topics as deployment, financing, and management are also discussed. The course will include guest lectures and possibly field visits.
Lecture: 3 Lab: 0 Credits: 3

CAE 581

Algorithms in Transportation
Modeling and analysis of transportation network problems through the design, analysis, and implementation of algorithms. Emphasis on the use of quantitative and qualitative methods of operations research to model system performance. Covers fundamental data structures, complexity analysis, memory management, recursive programs, application of graph theory, and network analysis to transportation problems, analytical formulations, and solution algorithms for origin-destination estimation, static and dynamic traffic assignments, and transportation resource allocation.
Lecture: 3 Lab: 0 Credits: 3

CAE 582

Structural Wind and Earthquake Engineering
Introduction to nature of wind, aerodynamic wind-loading and design. Strong ground motion phenomenon. Investigation of the response of structures to dynamic and pseudo dynamic wind, earthquake, shock waves and other deterministic and probabilistic loadings. Design criteria for buildings and nuclear power stations, special topics in lifeline earthquake engineering.
Prerequisite(s): CAE 529 with min. grade of C or Graduate standing
Lecture: 4 Lab: 0 Credits: 4

CAE 583

Performance-Based Structural and Seismic Design of Buildings and Bridges
This course covers performance-based structural and seismic design (PBSSD) for buildings and bridges. The course will begin with brief reviewing and critical discussion on conventional code-based seismic design followed by the development of the concept and applicability of this new alternative and advanced PBSSD. Computer methods in linear dynamic, nonlinear static, and dynamic analyses will be surveyed and discussed as primary tools in PBSSD. Ample case studies from real-world projects are carried out throughout the course. These case studies include the PBSSD of special structures, tall buildings, and those that building code-based design is not applicable.
Prerequisite(s): CAE 529 with min. grade of C or Graduate standing
Lecture: 3 Lab: 0 Credits: 3

CAE 584

Stormwater Management
Basic principles of storm water management; hydrology and hydraulics of excess water; excess water management and design; sewer system design and management, storm water detention systems; flood plain system design; risk based design of drainage systems; practical and case study problems.
Prerequisite(s): CHE 301 or MMAE 313 or CAE 302 or CAE 209
Lecture: 3 Lab: 0 Credits: 3
CAE 586
Seismic Design of Building and Bridge Structures
The course covers six topics, as listed in the course outline, on seismic design of steel and R/C building structures and bridges. In addition to offer fundamentals and experiences in seismic design through design examples, it is also assumed that structural engineers who are preparing for their Structural Engineer License Exam might find extremely helpful.
Prerequisite(s): (CAE 431 with min. grade of C and CAE 432 with min. grade of C) or Graduate standing
Lecture: 3 Lab: 0 Credits: 3

CAE 587
Commissioning of Construction Projects
This course provides students with the methods and process of Commissioning, a high-level engineering skill in construction projects of independently verifying that the design and the construction meets the Owner’s bargained for quality. It enumerates tracking the processes of equipment approval, installation, individual equipment testing and manufacturer training, programming of digital controls, and operational tests in high and low states to verify that end product of the construction project meets the Owner’s requirements. The Construction Standard Institute (CSI) of the United States and Canada MasterFormat is used as a guide to specific types of commissioning.
Corequisite(s): CAE 569
Lecture: 3 Lab: 0 Credits: 3

CAE 588
Computing, Informatics, and Advanced Information Technologies in Construction Engineering
The course covers concepts in computing, processing information and data, representation, and reasoning strategies to be applied in construction engineering tasks during the whole life cycle of a project. The course presents advanced information technologies used to manage project design and construction operations, including application methods and techniques. Topics allow the student to acquire a broad understanding of information, data, and knowledge within any construction process. The instructor will also include research-level topics of discussion concerning the use of state-of-the-art technologies within the civil and construction engineering practice, such as the Internet of Things (IoT), robotics, digital twins, ontologies, and technologies along the virtuality-reality continuum (e.g., augmented reality, mixed reality).
Lecture: 3 Lab: 0 Credits: 3

CAE 589
Groundwater Hydrology and Sampling
Lecture: 3 Lab: 0 Credits: 3

CAE 590
Geotechnical Landfill Design and Maintenance
Regulatory and legal issues, site selection and assessment, geotechnical-subsurface investigation, clay mineralogy and clay-water-electrolyte system, linear and leachate-control-systems design, stability of landfill slopes, cover design, construction and operation, final use and remediation design.
Prerequisite(s): CAE 323 with min. grade of C or Graduate standing
Lecture: 3 Lab: 0 Credits: 3

CAE 591
Research and Thesis for M.S. Degree
Research and Thesis for M.S. Degree.
Credit: Variable

CAE 594
Research Problems
Credit: Variable

CAE 595
Current Issues in the Construction Industry
The task organization and operation of Design and Construction projects is reviewed. Each student selects a major issue/problem they have experienced on their projects as a basis for a podcast interview with the Professor. The other students in the class will provide input by direct participation or by use of the discussion board for that podcast. At the end of the semester each student submits a paper on the strategic directions of the Construction Industry using all the podcasts and their experience as a basis. At least 3 years’ experience in the U.S. Canadian design and construction industry where project organizations are task organizations are task organized from many different companies and parties using contracts. The student has worked with the processes of RFP/Bid preparation, monthly Pay Apps, and Change Orders (Mods).
Lecture: 1 Lab: 3 Credits: 3

CAE 597
Special Problems
Graduate course work in the problem subject matter. Subject matter will vary with the interests and background of students and instructor. Design or research problems may be assigned from the areas of architectural, construction, geotechnical, geoenvironmental, structural, or transportation engineering.
Credit: Variable

CAE 598
Special Topics
A special topic in civil or architectural engineering at the graduate level.
Credit: Variable

CAE 599
Graduate Workshop
Graduate workshop.
Lecture: 0 Lab: 0 Credits: 0

CAE 691
Research and Thesis for Ph.D. Degree
Research and Thesis for Ph.D. degree.
Credit: Variable
ENGR 521
Risk Management in Engineering Projects
In project management, a risk is considered an uncertain event that may have a positive or a negative impact on project objectives. Managing identified threats individually through customized strategies is key to project success. Similarly, opportunities must be leveraged for better project outcomes. Implementation of an effective risk management process is imperative for today’s complex projects. This course presents a five-step process to manage project threats as well as opportunities. On every project, students will be able to identify and analyze risks and develop response strategies for each identified risk and take proper response action to manage the risks. Industry best practices and quantitative tools and simulations are used to analyze risk.
Lecture: 3 Lab: 0 Credits: 3

ENGR 531
Urban Systems Engineering Design
ENGR 531 is a project-based course where students will explore integrated designs of urban systems. Each project will apply the students’ engineering disciplines (such as structures, transportation, building science, construction engineering and management, environmental engineering) in a comprehensive analysis that considers the economic, human, and environmental issues associated with the project.
Lecture: 3 Lab: 0 Credits: 3

ENGR 532
Urban Systems Engineering Seminar
ENGR 532 is an active seminar course that emphasizes current topics in urban systems engineering. Invited speakers will include researchers and representatives from current practice, such as municipal and regional planners and consultants. Appropriate readings will be assigned in advance of each speaker to guide students in preparation for active discussion with each speaker. Each student will also write a term paper on an urban systems engineering topic of their choice, connecting material from the assigned reading, the speakers, and additional references selected by the student.
Lecture: 3 Lab: 0 Credits: 3

ENGR 534
Product Design and Innovation
This course covers all aspects of planning new products or services that are commercially viable and add to a company’s suite of offerings. It includes such topics as user research, market analysis, need/problem identification, creative thinking, ideation, concepting, competitive benchmarking, human factors, prototyping, evaluation, and testing. The course includes creative, analytical, and technical skills in a balanced approach using such teaching methods as case studies, individual exercises, and group projects.
Lecture: 3 Lab: 0 Credits: 3

ENGR 539
Robotic Motion Planning
Configuration space. Path planning techniques including potential field functions, roadmaps, cell decomposition, and sampling-based algorithms. Kalman filtering. Probabilistic localization techniques using Bayesian methods. Trajectory planning.
Lecture: 3 Lab: 0 Credits: 3

ENGR 572
Construction Cost Accounting and Control
Lecture: 3 Lab: 0 Credits: 3
ENGR 573
Construction Contract Administration
Lecture: 3 Lab: 0 Credits: 3

ENGR 574
Economic Decision Analysis in Civil Engineering
Basic economic concepts including interest calculations, economic comparison of alternatives, replacement decisions, depreciation and depletion, tax considerations, and sensitivity analysis. Evaluation of public projects, the effect of inflation, decision making under risk and/or uncertainty, economic decision models. Case studies from the construction industry.
Lecture: 3 Lab: 0 Credits: 3

ENGR 575
Systems Analysis in Engineering
Management and system concepts, linear programming, graphical methods, Simplex, two-phase Simplex, the transportation problem, the assignment problem, integer programming, and sensitivity analysis. System modeling by activity networks; maximal-low flow, longest-path and shortest-path analyses, flow graphs, decision-tree analysis, stochastic-network modeling, queuing systems, and analysis of inventory systems. Case studies from the construction industry.
Lecture: 3 Lab: 0 Credits: 3

ENGR 576
Nano Manufacturing
This course covers the general methods used for micro- and nano-fabrication and assembly, including photolithography techniques, physical and chemical deposition methods, masking, etching, and bulk micromachining as well as self-assembly techniques. It also covers nanotubes, nanowires, nanoparticles, and the devices that use them, including both electronic and mechanical-electronic systems, as well as nano-structural materials and composites. Focus is on commercially available current processes as well as emerging technologies and evolving research areas. Sensing and instrumentation as well as nano-positioning and actuation are covered briefly.
Lecture: 3 Lab: 0 Credits: 3

ENGR 577
Additive Manufacturing
This course examines the fundamentals of a variety of additive manufacturing processes as well as design for additive manufacturing, materials available, and properties and limitations of materials and designs. It also examines the economics of additive manufacturing as compared to traditional subtractive manufacturing and other traditional techniques. Additive techniques discussed include 3D printing, selective laser sintering, stereo lithography, multi-jet modeling, laminated object manufacturing, and others. Advantages and limitations of all current additive technologies are examined as well as criteria for process selection. Processes for metals, polymers, and ceramics are covered. Other topics include software tools and connections between design and production, direct tooling, and direct manufacturing. Current research trends are discussed.
Lecture: 3 Lab: 0 Credits: 3

ENGR 578
Introduction to Digital Manufacturing
This course is about the digital revolution taking place in the world of manufacturing and how students, workers, managers, and business owners can benefit from the sweeping technological changes taking place. It is about the change from paper-based processes to digital-based processes all through the design/manufacturing/deliver enterprise, and across the global supply chain. It touches on digital design, digital manufacturing engineering, digital production, digital quality assurance, and digital contracting, from large companies to small. There is also a significant focus on cyber security and the new types of threats that manufacturers face in the new digital world. Other topics covered include intelligent machines, connectivity, the digital thread, big data, and the Industrial Internet of Things (IIoT).
Lecture: 3 Lab: 0 Credits: 3

ENGR 579
Engineering Management Capstone Experience
Students apply the knowledge they have acquired in the Engineering Management program to a specific problem or case study. Projects will be identified and mentored in conjunction with faculty and industrial partners. A final report or business plan is required that reflects the focus of the capstone project.
Lecture: 3 Lab: 0 Credits: 3

ENGR 580
Product Development for Entrepreneurs
Elements of product development (mechanical and electrical), manufacturing and production planning, supply chain, marketing, product research, and entrepreneurship concepts are taught in this class. In this course, student teams will be required to create a compelling product that has potential to be sold in today's marketplace. They will be required to create functional prototypes of their product for people to use and critique. If successful, students will be allowed to put their product on Kickstarter.com and take orders for delivery after the class is complete while potentially fostering their own business as a result of this course.
Lecture: 3 Lab: 0 Credits: 3
ENGR 596
Practical Engineering Training
This course is a mentored, immersive practical engineering training. Students learn under the direction of professional engineers and practicing engineers by working on real engineering projects. The student will perform hands-on engineering, including learning and developing/applying engineering principles and concepts to complete the project assigned to the student. The student will apply engineering ethics and safety during their practical engineering training. Students will communicate the results of their work in written and oral communications. Students will receive assignments of varying complexity consistent with their graduate standing.
Lecture: 0 Lab: 9 Credits: 3

ENGR 598
Graduate Research Immersion: Team Project
This course provides a faculty-mentored immersive team-based research experience. Research topics are determined by the faculty mentor’s area of research. In addition to the mentored research, students participate in seminars, prepare a written report of their research findings, and present their research findings at a poster expo.
Lecture: 3 Lab: 0 Credits: 3

ENGR 599
Graduate Research Immersion: Individual
This course provides a faculty-mentored immersive research experience. Research topics are determined by the faculty mentor’s area of research. In addition to the mentored research, students participate in seminars, prepare a written report of their research findings, and present their research findings at a poster expo.
Lecture: 3 Lab: 0 Credits: 3

ENVE 501
Environmental Chemistry
Chemical processes in environmental systems with an emphasis on equilibrium conditions in aquatic systems. Processes examined include acid-base, dissolution precipitation, air-water exchange, and oxidation-reduction reactions. Methods presented for describing chemical speciation include analytical and graphical techniques as well as computer models.
Prerequisite(s): ENVE 402 or CAE 402
Lecture: 3 Lab: 0 Credits: 3

ENVE 503
Occupational and Environmental Health and Safety
This course is intended to introduce students to the basics of occupational and environmental safety and health. Topics include fundamental principles in industrial hygiene and occupational and environmental safety based in the anticipation, recognition, evaluation, and control of chemical, biological, physical, and ergonomic hazards that can be encountered in the workplace and other settings. Applications include indoor air pollution control, natural disaster mitigation, and infectious disease transmission and control.
Lecture: 3 Lab: 0 Credits: 3

ENVE 506
Chemodynamics
Processes that determine the fate and transport of contaminants in the environment. Upon successful completion of this course, students should be able to formulate creative, comprehensive solutions to transport problems, critically evaluate proposed solutions to transport problems, and acquire and integrate new information to build on these fundamentals.
Prerequisite(s): ENVE 402 or CAE 402
Lecture: 3 Lab: 0 Credits: 3

ENVE 513
Biotechnological Processes in Environmental Engineering
Fundamentals and applications of biological mixed culture processes for air, water, wastewater, and hazardous waste treatment. Topics include biochemical reactions, stoichiometry, enzyme and microbial kinetics, detoxification of toxic chemicals, and suspended growth and attached growth treatment processes. The processes discussed include activated sludge process and its modifications, biofilm processes including trickling filters and biofilters, nitrogen and phosphorous removal processes, sludge treatment processes including mesophilic and thermophilic systems, and natural systems including wetlands and lagoons.
Lecture: 3 Lab: 0 Credits: 3

ENVE 522
Global Environmental Change and Sustainability Analysis
This course introduces students to concepts of global biogeochemistry and environmental sustainability, including the practice of life cycle assessment (LCA). The course begins with an overview of the global energy, water, carbon, and nitrogen cycles and their relationships to human activities. The focus then shifts to LCA, which is an analytical approach for quantifying the relationships between economic activities and environmental issues. LCA is often used to develop sustainability metrics to compare alternative approaches to meet economic needs such as transportation, food provision, and building construction. This course is open to all majors with familiarity in basic chemistry, but students will be expected to conduct quantitative analyses and perform basic engineering calculations.
Lecture: 3 Lab: 0 Credits: 3

ENVE 528
Modeling of Environmental Systems
To introduce students to mathematical modeling as a basic tool for problem solving in engineering and research. Environmental problems will be used as examples to illustrate the procedures of model development, solution techniques, and computer programming. These models will then be used to demonstrate the application of the models including simulation, parameter estimation, and experimental design. The goal is to show that mathematical modeling is not only a useful tool but also an integral part of process engineering.
Lecture: 3 Lab: 0 Credits: 3
ENVE 542
Physicochemical Processes in Environmental Engineering
Fundamentals and applications of physicochemical processes used in air, water, wastewater, and hazardous waste treatment systems. Topics include reaction kinetics and reactors, particle characterization, coagulation and flocculation, sedimentation, filtration, membrane separation, adsorption, and absorption.
Prerequisite(s): ENVE 404
Lecture: 3 Lab: 0 Credits: 3

ENVE 543
Carbon Capture, Utilization, and Storage
To address the climate impacts of anthropogenic sources of carbon dioxide (CO2), it has become increasingly important to focus on solutions for CO2 removal processes, especially directly from CO2 emission sources. Carbon capture and sequestration/storage (CCS) is the process of capturing CO2 formed during power generation and other industrial processes and sequestering it so that it is not emitted into the atmosphere. CCS technologies have significant potential to reduce CO2 emissions in energy systems. This course will review and explore, in detail, the engineering design principles for solutions of carbon capture at the source or direct air capture (DAC) from the atmosphere, utilization, and storage. Topics include an overview of the importance and future potential of CCS and other technologies such as direct air capture; power generation fundamentals related to carbon emissions and our reliance on fossil energy; current state of research and development on carbon capture technologies; storage, monitoring, and utilization of CO2; CO2 transportation (e.g., pipeline and marine modes); and economics of technologies for removing CO2 from the atmosphere and additional methods of reducing CO2 concentrations and other greenhouse gases in the atmosphere.
Lecture: 3 Lab: 0 Credits: 3

ENVE 551
Industrial Waste Treatment
Industrial waste sources and characteristics, significance of industrial waste as environmental pollutants; applications of standard and special treatment processes including physical, chemical, and biological systems.
Prerequisite(s): ENVE 513* with min. grade of C or ENVE 542* with min. grade of C, An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 Lab: 0 Credits: 3

ENVE 561
Design of Environmental Engineering Processes
Design of water and wastewater treatment systems. System economics and optimal design principles.
Prerequisite(s): ENVE 513* with min. grade of C or ENVE 542* with min. grade of C, An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 Lab: 0 Credits: 3

ENVE 570
Air Pollution Meteorology
Physical processes associated with the dispersion of windborne materials from industrial and other sources. Atmospheric motion including turbulence and diffusion, mathematical models, and environmental impact assessment.
Lecture: 3 Lab: 0 Credits: 3

ENVE 576
Indoor Air Pollution
Indoor air pollution sources, indoor pollutant levels, monitoring instruments and designs, and indoor pollution control strategies; source control, control equipment and ventilation; energy conservation and indoor air pollution; exposure studies and population time budgets; effects of indoor air pollution; risk analysis; models for predicting source emission rates and their impact on indoor air environments.
Lecture: 3 Lab: 0 Credits: 3

ENVE 577
Design of Air Pollution Control Devices
Principles and modern practices employed in the design of engineering systems for the removal of pollutants. Design of control devices based on physical and chemical characteristics of polluted gas streams.
Lecture: 3 Lab: 0 Credits: 3

ENVE 578
Physical and Chemical Processes for Industrial Gas Cleaning
Application of physical and chemical processes in the design of air treatment systems; fundamentals of standard and special treatment processes.
Lecture: 3 Lab: 0 Credits: 3

ENVE 580
Hazardous Waste Engineering
Sources and characteristics of hazardous wastes, legal aspects of hazardous waste management, significance of hazardous wastes as air, water, and soil pollutants. Principles and applications of conventional and specialized hazardous waste control technologies.
Prerequisite(s): ENVE 506* with min. grade of C, An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 Lab: 0 Credits: 3

ENVE 591
Research and Thesis M.S.
Graduate research.
Credit: Variable

ENVE 597
Special Problems
Independent study and project. (Variable credit)
Credit: Variable

ENVE 691
Research and Thesis Ph.D.
Graduate research.
Credit: Variable